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Original Contributions Concerning the Glandular Structures Appertaining to the Human Eye and its Appendages.

ADOLF ALT, M. D.

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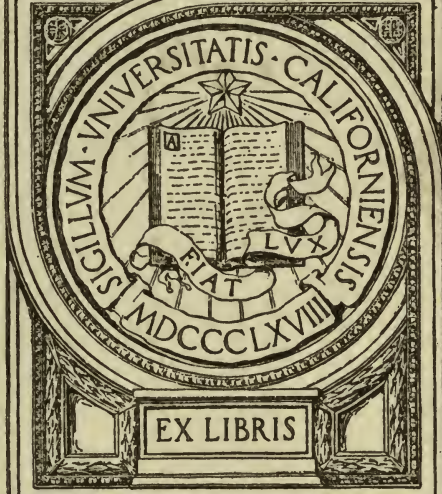

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Original Contributions Concerning the Glandular Structures Appertaining to the Human Eye and its Appendages.

With 71 Original Illustrations.

BY ADOLF ALT, M. D.,

PROFESSOR OF OPHTHALMOLOGY IN BEAUMONT HOSPITAL MEDICAL COLLEGE, ST. LOUIS.

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ORIGINAL CONTRIBUTIONS CONCERNING THE GLANDULAR STRUCTURES APPERTAINING TO THE HUMAN EYE AND ITS APPENDAGES.*

Adolf Alt, M. D.

PREFACE.

The studies and investigations which are the subject of this paper are the outcome of a desire to have as clear as possible an understanding of the glandular structures appertaining to the human eye and its appendages from personal knowledge.

It took a number of years to accumulate the very numerous specimens, the careful study of which furnished the basis for the descriptions here given. While part of the many eyelids which I have examined were obtained from suitable cases in my own practice, a large number came from the dissecting rooms of the Beaumont Hospital Medical College of this city through the kindness of Dr. R. W. Baker, the demonstrator of anatomy in this institution. Of necessity a great part of this anatomical material was of a pathological character, and it has, therefore, served for other studies as well.

As it seemed to me that the text-books which I know of, with but few exceptions, deal in a very insufficient manner with this interesting subject, I have thought it might be of some interest to place the results of my own investigations in this direction before the ophthalmic public. This may, perhaps, prove the more interesting, since by the efforts of numerous foreign ophthalmic surgeons, and in this country notably of Dr. C. R. Holmes of Cincinnati † the old operation of the removal of the lacrymal glands for incurable lacryma-

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* Presented by title to The Academy of Science of St. Louis, May 21, 1900.

† Archives of Ophthalmology. 28:1.

tion has of late been reintroduced and has become a legitimate surgical procedure.

The investigations herein recorded may claim to be original in so far as they were made, in a sense, as if I had known nothing of the literature on the subject. This was in reality the case with some of the more recent monographs which I did not and had no chance to consult until my researches, at least as far as my material would allow me, were finished.

The illustrations, except the three last ones, which are more or less schematic drawings, are made from photographs I took of my own specimens.

THE ORBITAL, PALPEBRAL AND CONJUNCTIVAL LACRYMAL GLANDS.

The lacrymal gland is usually spoken of as consisting of two separate parts, one the so-called orbital lacrymal gland and the other termed the inferior, palpebral, conjunctival or accessory lacrymal gland.

The orbital lacrymal gland, as its name denotes, is situated, at least to its greatest extent, within the orbital cavity. There it is located in the fovea lacrymalis which lies right behind the outer upper bony orbital margin in the processus zygomaticus of the frontal bone. Its anterior end usually slightly protrudes beyond the bony margin. The gland is held in this position by a connective tissue capsule which is united with the orbital periosteum by means of loosely interwoven trabeculae. This capsule is generally somewhat firmer on the nasal side of the gland.

When this gland is in toto removed from the fovea lacrymalis, its shape is seen to resemble to some extent that of an almond (Fig. 1). It is convex at the orbital surface, and more or less concave at its ocular (lower) side. Its posterior portion is usually thick and rounded, its anterior one thinner and sharper. The posterior part of the gland may, when it is well developed, reach back into the orbit about as far as the anterior third of its depth. The nasal edge usually reaches to the temporal margin of the superior rectus muscle.

However, the actual measurements of this gland, like those of other glands, are subject to great variations. As an inter-

esting fact, I may say, that in the Negro I have found this gland to be as a rule larger than in the Caucasian. I have seen it often to be twice as large or even more (Figs. 2, 3).

The orbital lacrymal gland forms a more or less compact glandular body. It consists of a large number of lobules united closely with each other by loose connective tissue in which its ducts and numerous blood vessels lie. These connective tissue trabeculae are united to its capsule.

The gland is of the acinous type and its structure has been correctly likened to that of the serous or salivary glands. The round or oval final acini are situated around and connected with small efferent ducts which, by their union in the direction towards the conjunctiva, form larger and larger excretory ducts. These acini consist of a membrana propria and a lining of cylindrical, or rather, conical secretory epithelial cells, with a large round or oval nucleus near their broader base which are arranged in a circle around a central lumen.

The secretion of this gland is carried to the conjunctival sac by means of a varying number of these excretory ducts which are lined with a cylindrical epithelium. The statement is made by numerous authors, that there are from 6 to 12 such excretory ducts. It does not seem to me that there are so many. I often found one of them, which also seemed to be the longest, to be considerably wider than the others.

These excretory ducts reach the conjunctiva of the fornix by a somewhat bent and wavy course; their external orifices lie in the temporal part of the conjunctival sac near the edge of the tarsal tissue.

Below the orbital lacrymal gland and separated from it by its capsule, the levator palpebrae superioris muscle and Müeller's non-striated muscle, and embedded in the loose connective tissue of the eyelid on the temporal side of the tarsus, lies the inferior or palpebral lacrymal gland (Figs. 1 to 5).

This gland consists of a varying number of smaller and larger lobules which are very much more loosely held together by the intervening connective tissue than those of the orbital gland, and therefore do not form as compact a body.

While this gland is usually thought to lie in the upper eye-

lid alone, I have in normal lids almost invariably found its lobules to reach downwards through and beyond the outer canthus into the lower eyelid (Figs. 6, 7). The glandular lobules here lie grouped around the temporal and sometimes even the lower edge of the tarsus. Similar lobules of glandular tissue, only still more loosely connected with and further apart from each other, are found in most eyelids to extend from the more compact temporal body of this palpebral glandular system towards the nasal side of the upper eyelid. These more isolated lobules may reach to the middle line of the eyelid and even somewhat beyond it (Figs. 8, 9). They lie in the loose tissue of the fornix of the conjunctiva or a little below it on the palpebral side. The farther away from the outer canthus, the smaller these glandular lobules usually are. Those found in the temporal side of the lower eyelid seem to be of a more uniform size. Yet, there is no absolute rule about this.

It seems that when speaking of the palpebral or inferior lacrymal gland, we have to include all of these separate and so widely dispersed glandular lobules. Their number in the aggregate may well reach up to 40 or more.

The structure of the glandular lobules is exactly the same as that of the orbital lacrymal gland. They differ in no particular. Their numerous efferent ducts, lined with cylindrical epithelium, lead their secretion to the conjunctival sac (Fig. 10). The statement has often been made and repeated, that the ducts of these glands are taken up by those of the orbital lacrymal gland around which, in part, they are grouped, before reaching the conjunctival surface. Whether this happens often, I cannot tell definitely in spite of my numerous specimens; but it may occasionally be the case. I find, that most frequently several of these lobules have an excretory duct in common, which runs separately from the excretory ducts of the orbital lacrymal gland to the conjunctiva. Such a duct has generally a wavy course and does not reach the conjunctiva by the shortest route (Figs. 10 to 16). The more widely separated and the totally isolated glandular lobules in the lower eyelid and those glands which extend in the upper eyelid towards its middle line, must of necessity

have their ducts apart from those of the orbital lacrymal gland, as they lie so far removed from them. The external orifices of these ducts lie in the upper conjunctival fornix and usually form a row, being arranged side by side. I may state here, that these excretory ducts pierce the conjunctival surface generally at a more or less acute angle in a downward direction, so that the upper lip overhangs the orifice (Figs. 11, 14).

Even in what appear to be perfectly normal conjunctivae, the orfiices of the ducts are frequently surrounded by a dense lymphoid infiltration in the adjoining tissue. This infiltration is frequently so dense that on surface specimens it may hide the openings. This condition may, perhaps, be the explanation for the repeated statements that in the normal conjunctiva of man lymph-follicles could be found. I here repeat the statement which I have made on other occasions, that, like Waldeyer, I have never found a true lymph-follicle in the human conjunctiva.

From the foregoing description it is apparent that a very large, though varying, amount of glandular tissue, of identically the same structure and most probably the same function as the orbital lacrymal gland, is situated in the temporal half of the eyelids above, respectively below, the fornix conjunctivae. The secretion of all of these glands, combined with that of the orbital lacrymal gland, is discharged into the conjunctival sac and, flowing over the surface of the eyeball, keeps it and the inner surfaces of the eyelids moist.

Yet, even a careful removal of all of this glandular tissue does not render the surface of the eyeball dry. There must, therefore, be still other glandular structures, which supply such a moistening liquid, and, in reality, a number of such glands do exist.

Almost without exception I find one such gland, consisting of 2 or 3, seldom 4 lobules, near the inner canthus in the nasal part of the upper eyelid, or a little higher up in the conjunctiva near the fornix (Figs. 17 to 20); another one, consisting usually of 2 lobules, I find in the nasal conjunctiva of the lower eyelid, below the lacrymal caruncle (Figs. 21, 22), and frequently one in the temporal side of the lower eyelid

somewhat nasally removed from the palpebral lacrymal gland.

When studying horizontal sections through the eyelids such little glands are sometimes found, also, to lie close to the temporal and nasal edges of the tarsus of the upper as well as the lower lid, and partly in the ocular conjunctiva. They are formed of one or two minute glandular lobules. All of these glands are of exactly the same histological structure as those generally recognized as lacrymal glands. Their excretory ducts, from their situation, are rather short. They, also, are lined with cylindrical epithelium. Their external orifice lies usually in the palpebral, sometimes in the ocular conjunctiva (Figs. 23 to 25).

There is no reason, as far as I can see, why these small isolated acinous glands should not also be looked upon as lacrymal glands, as they differ in no way histologically from them. The difference in size is the only one I can recognize.

The presence of these glands alone, then, could explain why, after the operative removal or the destruction of the orbital and the larger palpebral lacrymal glands in the temporal half of the eyelids, the surfaces of the eyeball and eyelids do not become dry. It is, furthermore, clear that when a chronic inflammation, involving the whole of the conjunctiva, gradually leads to its shrinkage and to the consequent obliteration of the excretory ducts and secondarily to atrophy of all these glands (and of some to be described presently), as for instance trachoma, xerophthalmus must result.

GLANDS SITUATED IN THE TARSAL TISSUE OF THE EYELIDS.

The tarsal tissue proper of the eyelids contains two forms of glands, namely, the so-called Meibomian glands and the acino-tubular (Waldeyer) glands.

The Meibomian glands are found in the upper lid to be about 30 in number, while in the lower lid they are only about 20. There are, however, individual variations as to these numbers. They are long, slender glandular structures, somewhat resembling the pancreatic glands, consisting each one of a central duct to which are attached numerous round, vesicle-like acini (Fig. 26). These central ducts

never quite reach the upper (in the lower eyelids the lower) edge of the tarsus. The acini begin somewhat removed from the external orifice of this central duct and sit upon it very much like grapes on the central stem. They form usually four rows around it, one on the posterior and one on its anterior surface, one on its nasal and one on its temporal side (Figs. 27, 28). The external orifices of the excretory ducts lie side by side at the free edge of the lid behind the lashes. The dermal epithelium reaches inwards into these ducts for some distance, as is particularly well shown in the eyelids of the Negro (Fig. 26).

The acini of these glands as well as their ducts are lined with several layers of flat polygonal epithelial cells. These continually undergo a fatty degeneration and thus form a sebaceous secretion which renders the lidmargins fatty and thus helps to retain the tear-fluid within the conjunctival sac. In their structure these glands differ in no way from the sebaceous glands of the skin; they differ only in size.

The length of the individual Meibomian glands varies according to the height of the tarsal tissue. Thus, the longest ones lie in the middle line of the eyelid, and from there they grow gradually shorter towards both canthi. The most nasally or temporally situated ones often consist only of the central duct and two or three acini.

I can find only one layer of Meibomian glands, and all statements, referring to two or even more layers, are undoubtedly due to oblique sections. In a general way these glands run parallel to each other and at right angles to the lidmargin. Yet, deviations from this rule are not uncommon (Fig. 28).

The second kind of glands, the acino-tubular ones (Waldeyer), are usually drawn and described as lying solely in the temporal part of the tarsus above (in the lower lid below) the Meibomian glands (Fig. 29 to 31). This seems to be their most frequent location, or at least, they seem to be generally best developed in this portion of the tarsus. They are however, at least in the upper eyelid, quite frequently found to be located, also, near and in the middle line (Figs. 23 to 25),

and sometimes, but rarely so, near the nasal edge of the tarsus (Fig. 32). While, as a rule, they are situated between the apex of the Meibomian glands and the upper (in the lower eyelid the lower) edge of the tarsus, they are not at all infrequently found to reach in between the Meibomian glands and as far down (or up) almost as the orifices of these glands at the lidmargin (Figs. 32 to 35).

The histological structure of these glands is also of the acinous type, and they do not essentially differ from the lacrymal glands, although their appearance and general arrangement are slightly modified by the dense tissue in which they lie embedded (Figs. 36, 37). Their lobules are formed of numerous round and oval acini which consist of a basal membrane lined with cylindrical (conical) cells arranged around a central lumen, with a round or oval nucleus near their base. The small excretory ducts coming from the acini unite into a larger one which is sometimes quite long and to which smaller acini are attached throughout its length, the small ducts of which empty directly into this large duct formed by the union of the ducts coming from the most distant acini. It is probably this arrangement which has led to their being named "acino-tubular" glands. Sometimes, however, and especially when these glands are situated between the Meibomian glands, this excretory duct is but very short. The excretory ducts of the acino-tubular glands are, also, lined with cylindrical epithelium, like those of the lacrymal glands. Their external orifice lies in the palpebral conjunctiva (Figs. 35, 38).

These acino-tubular glands are generally spoken of as muciparous glands. For what reason, I have been unable to determine, and it is not possible to examine their secretion chemically. Their structure as stated, with the slight modification due to density of the tissue in which they lie embedded, corresponds in every respect with the lacrymal glands. The microscopical staining reagents which seem to have a special affinity to mucous substances, as haematoxylin, Bismark-brown, and others, do not stain any part of these glands in particular. Now and then I have found a concretion in the excretory duct of such a gland, but this cannot be taken as proof of their

muciparous character, as just such concretions are also found in the ducts of the lacrymal glands (Fig. 39).

GLANDS SITUATED IN THE TISSUE OF THE LIDMARGIN.

In the dense tissue of the lidmargin, in front of the excretory ducts of the Meibomian glands, the cilia or eyelashes are implanted. These short curved hairs form three or four rather irregular rows and emerge from the skin of the anterior part of the lidmargin (Fig. 40). They are more numerous in the upper eyelid than in the lower one, numbering in the former from 100 to 150, in the latter from 50 to 70. These numbers are, of course, only approximately correct. The longest eyelashes lie in the middle line of the lids and from here they grow smaller and smaller in the direction towards the canthi. They are shortlived and drop out when about from 50 to 100 days old. The curvature of the eyelashes of the upper lid is concave upwards and convex downwards, while that of the eyelashes of the lower lid is just the reverse.

Each eyelash is accompanied by sebaceous glands, usually two, not infrequently three and four to one hair. These glands do not differ in any particular from other sebaceous glands of the hair of the skin and, therefore, it is not necessary to give here a special description.

There is, however, another kind of glands situated in the intermarginal tissue of the eyelids, more especially, between the roots of the eyelashes, which is of a somewhat peculiar structure. These glands have been called *modified sweat-glands*, although, as far as I can find, nothing is known concerning the character of their secretion (Figs. 41, 42).

In vertical (sagittal) sections through the whole thickness of the eyelids one or two such glands are usually seen to lie between the roots of two neighboring eyelashes or a little nearer to the lidmargin, sometimes farther inwards between the eyelashes and the tarsal tissue. In horizontal sections (Fig. 43) and sections which are made parallel to the surface of the eyelid, these glands are often found to be very numerous. (I have never succeeded in getting such sections parallel to the surface which would go through the whole width

of the eyelid on account of its curvature, but they often comprise about half or a little more of an eyelid. For the same reason, that is, the curvature of the eyelid, these sections can only in an approximate way be said to run parallel to the surface of the eyelid.)

Near the canthi where the eyelashes cease, I find, as a rule, a larger body of these glandular structures lying outside of the last eyelash, temporally as well as nasally.

These peculiar glands usually appear to consist of one or two rows of round or oval vesicle-like acini, which are sometimes quite large, and which probably communicate with each other (Figs. 44, 45). Half a dozen or so of such acini seem to constitute the gland. These usually terminate in one larger, more conically shaped acinus, a collecting chamber, from which the efferent duct of the gland takes its origin. While this arrangement is the one I have almost always found, I have now and then seen a gland which appeared to be altogether tubular, the tube being wound upon itself exactly as is the case with the sweat-glands of the skin (Figs. 42, 46). As this usually occurred in thicker sections it may, perhaps, be that the appearance I have above described, is due to the manner in which the section has cut through the windings of the tube, and that in reality we have to deal altogether with tubular glands. I have been unable to come to a definite conclusion as regards this point.

The efferent duct of these glands usually has a slightly arched course on its way to the lidmargin (Figs. 41, 42). There its orifice lies frequently within the duct of one of the sebaceous glands belonging to an eyelash. There are, however, many exceptions to this general rule, and I have found in almost every eyelid a number of external orifices of efferent ducts of modified sweat-glands which lie separately in the skin of the lidmargin.

The acini of these peculiar glands are lined with a short, almost cuboid cylindrical epithelium; the epithelial cells lining the efferent ducts appear more flattened.

I have frequently seen a fatty, grumous substance contained in the lumen of the acini of these glands which appeared exactly like the contents found in the acini of the Meibomian

glands. Like these it did not take up any stain and it was dissolved and totally disappeared, as soon as the specimen was cleared in oil of cloves. Of course, it is not permissible to conclude from this fact alone that these glands must be looked upon rather as modified *sebaceous* than as modified *sudoriferous* glands. Still, I think this point is worth mentioning. Neither does it seem very apparent, what role a watery secretion should play, when mixed with the fatty secretion of the sebaceous glands of the eyelashes. Furthermore, a watery secretion in this region would very likely lead to the overflow of the tears at the lidmargin, which is evidently not the case.

THE CARUNCULA LACRYMALIS AND THE GLANDS SITUATED IN ITS TISSUE.

The little rounded body of tissue lying at the nasal canthus between and slightly backwards from the folds coming from the upper and lower eyelids, which is called the lacrymal caruncle, consists to a large extent of glandular tissue and bears some small hairs on its surface.

In vertical, as well as in horizontal sections through this body, I find usually three larger sebaceous glands which, except in their smallness, differ in no particular from the Meibomian glands of the eyelids. They have the same central duct and the same acini, only in a more compact arrangement (Fig. 47).

Now and then one or two of the so-called modified sweat-glands are found between them, lying usually in the center of the body of the caruncle. They differ from those found in the tissue of the lidmargin only by being smaller and shorter.

With much more regularity, indeed, almost as a rule, I find one, and quite often two, small glandular bodies of the acinous type situated in the lacrymal caruncle (Figs. 47 to 50). One of these usually lies near the upper and the other nearer the lower edge of the caruncle. They differ in their structure in no way from the acinous glands found in the conjunctiva and eyelids, and are, therefore, probably little lacrymal glands like these. At least they do not react differently

against staining reagents and more especially they do not show any staining affinity which would prove that they are of a muciparous character.

Their short excretory ducts are lined with cylindrical epithelium, and their external orifice lies either on the surface of the lacrymal caruncle or in the plica semilunaris.

Aside from these glandular structures, usually some fat-tissue is inclosed in the connective tissue which forms the body of the caruncle. In one case, and in one only, I found a small amount of hyaline cartilage tissue embedded in the loose connective tissue near the lower margin of the lacrymal caruncle and between it and the plica semilunaris (Figs. 51, 52).

THE LACRYMAL DRAINAGE APPARATUS.

The tear fluid which has neither been evaporated nor used up in moistening the surfaces of the eyeball and the eyelids, is drained off into the nose at the nasal angle of the palpebral fissure by means of a special system of draining tubes.

This draining apparatus begins with the lacrymal puncta, two small oval openings which are situated at the apex of the lacrymal papillae. These papillae are little cone-shaped elevations which lie in the lidmargins in line with, and to the nasal side of, the orifices of the Meibomian glands in the tarsal part of the eye-lids. The lower papilla lies, as a rule, a little farther removed temporally from the inner canthus, than the upper one.

From the puncta the lacrymal canaliculi start by which the tear-fluid is carried to the lacrymal sac. Each canaliculus may be divided into two parts, namely, a more or less vertical (Fig. 53) and a more or less horizontal one (Fig. 54). The first part, which is by far the shorter, runs from the lacrymal punctum upwards (in the lower eyelids downwards), and inwards, nearly at a right angle to the lidmargin. It is from 1.5 to 2 mm. long. The second, the so-called horizontal, part, runs in the direction towards the nose until it reaches the lacrymal sac.

Just inwards from its orifice at the lacrymal punctum the vertical part is generally very narrow (Fig. 55), and then

widens out more gradually. Where it makes the sudden bend to form the horizontal part, it usually has a diverticle (Fig. 56), which bulges out from its temporal side into the tissue of the eyelid. This diverticle is formed just at the end of the vertical part, and runs in a horizontal direction and is sometimes comparatively large. Quite frequently there is another diverticle in the horizontal part just at its beginning which runs in a more vertical direction.

The horizontal part of the upper canaliculus is about 7 mm. long and that of the lower canaliculus is a little longer. As stated above, the course of this portion of the canaliculi is not in reality horizontal, as the two gradually bend toward each other. Moreover this part of the canaliculi does not run in a straight line, so to speak, but is quite wavy, sometimes even tortuous (Fig. 57).

Just before reaching the temporal wall of the lacrymal sac the two canaliculi may, and as a rule do, join together and form one larger collective tube (Fig. 58). The length of this tube varies materially in different individuals, and it may be so short that it can hardly be recognized as a separate part. In other cases the two canaliculi reach and enter the lacrymal sac separately and ununited.

From their beginning at the lacrymal puncta to their entrance into the lacrymal sac the canaliculi are formed by a membrana propria, the connective tissue of which is largely intermingled with elastic elements. This membrana propria is lined with lamellated polygonal pavement epithelium (Fig. 59) which often forms a dozen or even more layers, seldom fewer than ten.

By means of these canaliculi, as stated, the tear-fluid is drained from the conjunctival sac into the larger receptacle, the lacrymal sac, and again from this into the nose by means of the nasal lacrymal duct.

The lacrymal sac (Fig. 60), lies in the fossa lacrymalis formed by the lacrymal bone and the frontal process of the supramaxillary bone, and between the branches of the internal palpebral ligament. It forms a comparatively narrow, almost slit-like, cavity, which has a great many diverticles and folds. Its epithelium consists of a basal layer of more cuboid cells

and of an inner layer of cylindrical cells. I have never seen ciliated cells (Figs. 59, 61).

The material of lacrymal sacs which I have been able to obtain for microscopical study has been rather limited and I have seldom had an entire lacrymal sac for examination. Usually it was only the upper and temporal part. I therefore cannot give from my own knowledge a more detailed description of its structure and will refer only to one point of interest, which, more especially, belongs to this paper, dealing, as it is, with the glandular organs belonging to the eyeball and its appendages.

It has been, and still is, a moot question, whether or not true glandular tissue is found in the walls of the lacrymal sac. From my specimens I cannot see how the existence of such glandular tissue can be doubted. As to the character of the glands and their secretion we can only speculate by comparison with other glands. I find usually two forms of glands and both of these often in considerable numbers, especially in the wall opposite the entrance of the collecting tube of the canaliculi.

The one kind is of the acinous type and corresponds in its structure exactly with the acinous glands found in the eyelids, conjunctiva and caruncle (Figs. 62 to 66). The structure of the other kind is more that of tubular glands, like the sudoriferous glands (Figs. 67, 68.)

I have never had an occasion to examine the structure of the nasal lacrymal duct.

REMARKS ON THE LITERATURE CONCERNING THE SUBJECTS OF THIS PAPER.

In how far, what I have found and described in the foregoing pages corresponds with or disagrees with what other investigators on this subject have found and laid down in literature, may be judged from the following brief survey of the more important works on the subject from the literature at my disposal.

I started out more particularly on this investigation, because I could get no satisfactory explanation as to what glands were referred to by the different authors, when speaking of

the "glands of Krause." As I could not procure Krause's own original description * I had to rely on what the text-books could give me, and this is what I found.

H. Frey † states that "in man we find small acinous glands, so-called *mucous* glands (according to Henle '*accessory lacrymal* glands'). They lie in the fornix of the conjunctiva between the tarsal tissue and the eyeball, and there are in the upper eyelid as many as 42 of them, in the lower eyelid from 2 to 6."

What Frey here refers to, are probably the lacrymal glands forming the palpebral or inferior lacrymal gland and the adjoining separate lobules which I have described, and which together may number about 40. Why, however, he calls them *mucous* glands, Frey does not explain.

W. Waldeyer ‡ says: "The *acino-tubular* glands in man lie in certain distinct localities, at the edge of the tarsus nearest the fornix, and *with preference in its nasal part*. There they are found, partially along the edge of the tarsus, and partially within the tissue of the tarsus itself. They are more numerous in the upper eyelid than in the lower one; according to *Krause and his pupil Kleinschmidt* there are about 42 of them in the upper and from 6 to 8 in the lower eyelid. Their excretory ducts open into the conjunctiva of the fornix. The glandular body belonging to an excretory duct is relatively large and consists of short tubular glandular chambers to which round acini are attached in large numbers." Yet, in the text to his beautiful illustration, he calls the acinous glands lying buried *wholly within the tarsal tissue itself, the acino-tubular glands*.

Surely it is utterly impossible from these two apparently authoritative descriptions to arrive at a clear and distinct idea of what is meant by the term "Krause's glands." Frey calls them mucous glands or, with Henle, accessory lacrymal glands, and Waldeyer states that they lie with preference in

* Zeitschrift für rationelle Medicin. **4**: 337. (1854).

† Handbuch der Histologie and Histochemie des Menschen. 673. Leipzig. 1874.

‡ Handbuch der gesammten Augenheilkunde, von A. Graefe u. Th. Saemisch. 1^1: 238. Leipzig. 1874.

the *nasal* side of the eyelid and calls them *acino-tubular* glands. Yet, both of these authors agree in stating that they found 42 such glands in the upper eyelid, and but slightly differ as to the minimum number in the lower eyelid, while they again agree as regards their maximum number.

In my description I have, therefore, refrained from using this term for any of the glands which I have found. I may, however, state that the idea of most authors seems to be that the glands which are found in the conjunctiva of the nasal part of the upper eyelid are "Krause's glands." That the number of these glands is very small and never comes near being 42, has been seen from my description. That number can only refer to the palpebral lacrymal glands.

E. Fuchs* says: "Upon the fornix, especially in its *nasal half*, lie the acinous glands of Krause, while *in the temporal half of the tarsus* are found lobules similar in character but more densely packed, representing *the inferior lacrymal gland*." This may, perhaps, sound differently in the original. Certain it is, that the inferior or palpebral lacrymal gland does *not lie in the tarsus*.

On page 560 of the same text-book, Fuchs makes the statement (translation) that the *inferior* lacrymal gland consists *of only one or two lobules*, for which reason it is also known as the accessory lacrymal gland.

It does not seem possible that by these two statements he refers to one and the same glandular structure.

A good description, both of the orbital and of the inferior lacrymal gland, is given by E. Bock in a monograph on the lacrymal gland in health and disease.†

The best, most extensive and most careful researches and descriptions, and those which most nearly correspond with what I have found, were made by A. Terson, whose excellent monograph ‡ has come to my knowledge and into my posses-

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* Text-book of Ophthalmology. Translated by A. Duane. 2d American edition. New York. 1899. In the text beneath *Fig. 164* (p. 561).

† Zur Kenntniss der gesunden und kranken Thraenendruese. Wien. 1896.

‡ Les glandes lacrymales conjonctivales et orbito-palpébrales. L'ablation des glandes lacrymales palpébrales. Paris. 1892.

sion only when my investigations on this subject were, so to speak, closed.

For macroscopic inspection Terson clears the whole eyelids up, by means of tartaric or acetic acid. He says: "In the outer third of the specimen the palpebral lacrymal gland with *its own excretory ducts* and those of the orbital lacrymal gland is plainly seen." Further on: "It is not difficult to recognize a long line of very much smaller glands, forming, as Mr. Panas has so happily expressed it, a sort of 'milky way' in the upper conjunctival cul-de-sac. Of these glands there is a continuous row, and they grow gradually larger towards the inner angle."

Further on, he says: "In the lower cul-de-sac I find a few glands very similar to those in the upper one, but they do not reach the inner angle and are situated in that half of the lower eyelid which lies close to the palpebral lacrymal gland."

In these particulars Terson's description varies but little from my own.

His description of the acino-tubular glands in the tarsal tissue, also, agrees very well with mine. His experience has, also, been that these glands are found most frequently in the *temporal* half of the tarsal tissue, but often, too, in the nasal or other parts. Contrary to my experience, he finds their excretory ducts to be very long and very tortuous. He also has found, that their duct may pass down, in between the Meibomian glands. He further states that the epithelium of these glands as well as that of their excretory ducts appears identical with that of the acinous glands of the fornix, and that the external orifices of the excretory ducts of the acino-tubular glands lie in the conjunctiva of the *upper* cul-de-sac or at other points of the tarsus and often even very near the lidmargin.

From this it would appear, that he never found such acino-tubular glands in the *lower* eyelid.

With regard to the glands found in the walls of the lacrymal sac, a very exhaustive paper by K. Joerss has appeared as No. 35 of Deutschmann's Beitraege zur Augenheilkunde, Leipzig, October 29th, 1898. (Beitraege zur normalen and

pathologischen Histologie des Thraenenschlauches). Joerss made his studies on excised lacrymal sacs, and one of his objects was to see, whether *true glands* could be found in the lacrymal sac, or not. In consequence, he devotes considerable space to this question and his conclusion is that, contrary to the statements of other investigators, true glands are really sometimes found lying in the normal mucous membrane of the lacrymal sac; but, according to his investigation, they are *serous glands, of the type of Krause's glands of the conjunctiva.* Mucous glands, according to him, have, thus far, been found with certainty only at the orifice of the nasal lacrymal duct in the nose, and it is still a moot question, whether these mucous glands belong in reality to the nasal lacrymal duct or to the mucous membrane of the nose. This investigator has, therefore, seen only one form of glandular tissue lying in the walls of the lacrymal sac, namely the acinous form, which seems to be the most frequent one of the two forms which I have found and described.

It is a strange fact, that aside from Waldeyer's article in Graefe & Saemisch's Cyclopaedia, mentioned above, and its translation into French in De Wecker's Traité complet d'ophtalmologie, and of the parts referring to the eyelids and lacrymal apparatus in Fuchs' text-book, the text-books on ophthalmology in general deal but very insufficiently with the glandular structures which are the subject of these investigations. Especially, in the first volume of the large, very recent, and generally admirable system of diseases of the eye, published by Norris & Oliver, Philadelphia, 1897, in the able article on the anatomy of the orbit and the appendages of the eye by T. Dwight, these points, it seems to me, are passed over too lightly. The lacrymal caruncle, for instance, though not a very important organ, might have received a little more attention than is expressed in the following words: "A raised pinkish little body, the lacrymal caruncle (Vol. I, p. 80)." The largest amount of the literature on the subjects here considered, is dispersed in journals and magazines which are not, as a rule, even ophthalmological ones, and it is, therefore, not easily obtained.

With regard to the small portion of hyaline cartilage

tissue which in one instance I found just below the lacrymal caruncle, I have detected only one statement in literature of a somewhat similar occurrence. In the text-book of A. Boehm and M. von Davidoff * the following statement is made (p. 349): "The third eyelid, the plica semilunaris, when well developed, contains a small spicule of hyaline cartilage."

In illustrating the details of their descriptions of the eyelids, most text-books give a longitudinal (sagittal) section through the thickness of the upper lid near the temporal canthus. From the descriptions here given, it is clear that one such drawing (not even excluding Waldeyer's often copied and classical one) cannot be sufficient, as the details of the tissues of the eyelids differ so very materially in their different portions (Figs. 69 to 71).

EXPLANATION OF ILLUSTRATIONS.

Plates I–XXXVI.

Plate I. — 1, Vertical (sagittal) section through the orbital lacrymal gland (A) and the more compact portion of the inferior or palpebral lacrymal gland (B), from a negro. — 2, Vertical (sagittal) section through the temporal outer third of the upper eyelid and the eyeball, from a white individual, showing the orbital and part of the palpebral lacrymal gland. — 3, Section the same as in Fig. 2, from a negro. The magnifying power under which the last two photographs were taken being the same, the great difference in size of the two orbital lacrymal glands is evident.

Plate II. — 4, From a negro. Section the same as in Figs. 2 and 3, but still further toward the temporal canthus, showing a large number of lobules belonging to the palpebral lacrymal gland.

Plate III. — 5, Part of the palpebral lacrymal gland of Fig. 2 under a higher magnifying power. Above, part of the orbital lacrymal gland; to the left, the orbicularis muscle; to the right, the conjunctiva, sclerotic and choroid. The palpebral gland is seen to be separated from the orbital one by the tendon of the levator palpebrae superioris and the nonstriated muscle of Mueller. — 6, Vertical (sagittal) section through both eyelids at the temporal canthus, showing lobules of the palpebral lacrymal gland in the lower eyelid as well as in the upper one, from a negro.

Plate IV. — 7, Vertical (sagittal) section through the lower eyelid near the temporal canthus (white), showing a Meibomian gland (A), below it acino-tubular glands (B), and below these, three lobules of the lower

* Lehrbuch der Histologie des Menschen, einschliesslich der mikroskopischen Technik. Wiesbaden. 1898.

palpebral lacrymal gland with an excretory duct between them. To the left the orbicularis muscle. — 8, Vertical (sagittal) section through the upper eyelid and eyeball (white), just through the middle line. The small round dark body in the subconjunctival tissue above the tarsus (↝) is an isolated small lacrymal gland.

Plate V. — 9, The same lacrymal glands as in Fig. 8, under a high magnifying power. — 10, Three lobules of the palpebral lacrymal gland in the upper eyelid, and an excretory duct.

Plate VI. — 11, The distal end and external orifice of one of the excretory ducts of the orbital lacrymal gland (vertical section). — 12, Several lobules of the palpebral lacrymal gland of the upper eyelid; upwards an excretory duct from the orbital lacrymal gland. The epithelium of the conjunctiva has fallen off.

Plate VII. — 13, Vertical section through two lobules of the palpebral gland, one with its excretory duct, upper eyelid. — 14, A large lobule of the palpebral lacrymal gland with its excretory duct, upper eyelid.

Plate VIII. — 15, A large lobule of the palpebral lacrymal gland with its excretory duct. To the right of it a transverse section of an excretory duct from the orbital lacrymal gland. The conjunctival epithelium has fallen off. — 16, The external orifice of the excretory duct of a small isolated lacrymal gland in the conjunctiva. Lymphatic infiltration around and near it. To the left the bulbar conjunctiva. The epithelium has fallen off.

Plate IX. — 17, Small acinous gland in the upper eyelid close to the nasal canthus (↝). Vertical section through upper eyelid and eyeball. The lacrymal caruncle is seen below. — 18, The same gland under a higher magnifying power.

Plate X. — 19, 20, Acinous glands from the conjunctiva near the lacrymal caruncle, upper eyelid.

Plate XI. — 21, Horizontal section through the lower eyelid a little below the caruncle. An acinous gland imbedded in the loose connective tissue. Upwards to the left side the conjunctival sac. — 22, A part of the same gland and its duct under a higher magnifying power.

Plate XII. — 23, Horizontal section through the eyelids showing the tarsal tissue, including some Meibomian glands, some acino-tubular glands in the middle line, and small acinous glands in the conjunctiva at both the temporal and nasal edges of the tarsus (A, B). — 24, The same. The skin and orbicular muscle torn off.

Plate XIII. — 25, Similar section to Figs. 23 and 24. — The dark lines in the conjunctiva represent the lymphatic infiltration. — 26, Somewhat oblique vertical section through the upper eyelid, showing the lower part of a Meibomian gland and its excretory duct. To the right of it appears to be a second layer of glandular tissue; this is, however, only apparent and due to the obliqueness of the section. To the right of the excretory duct lies the muscle of Riolan and the dark root of an eyelash (negro).

Plate XIV. — 27, Vertical section through the tarsal tissue and Meibomian glands parallel to the surface, from the lower eyelid, close to the conjunctival surface. — 29, Section parallel to the surface through the temporal third of the upper eyelid, showing Meibomian glands with dilated central ducts, and above them the acino-tubular gland as dark patches.

Plate XV. — 28, Similar section to that shown in Fig. 27.

Plate XVI. — 30, The same section as shown in Fig. 29, from the lower eyelid. Near the lidmargin in both of these figures a number of dilated modified sweat-glands appear as small white spots. — 31, Horizontal section from near the upper edge of the tarsus of the upper eyelid, showing the acino-tubular glands in the temporal side; also, a small acinous gland in the conjunctiva. Below is seen the bulbar conjunctiva.

Plate XVII. — 32, Horizontal section through the tarsus of the upper eyelid just above the nasal canthus. There are a number of transverse sections of Meibomian glands and a large compact body of acino-tubular glands in the nasal part of the tarsus (A). — 33, Horizontal section through the central part of the upper eyelid. In the middle line acino-tubular glands are seen lying between the Meibomian glands at A.

Plate XVIII. — 34, Section the same as in Fig. 33, but nearer the lidmargin. In the middle line, at A, a small piece of an acino-tubular gland with its excretory duct is seen; also, its external orifice in the palpebral conjunctiva. — 35, A similar section under a higher magnifying power. To the right and left side of the acino-tubular gland a Meibomian gland is seen.

Plate XIX. — 36, Vertical section through the lower eyelid, near the temporal canthus. Downwards, the very much dilated central duct of a Meibomian gland; above it a number of acino-tubular glands, undergoing atrophy. The conjunctiva to the right shows changes due to chronic blennorrhoea. — 37, Acino-tubular gland from the upper eyelid under a high magnifying power. A great many acini are atrophied.

Plate XX. — 38, Vertical section of the upper eyelid; high magnifying power. In the left lower corner the dilated apex of a Meibomian gland; above it lobules of an acino-tubular gland torn apart in mounting; also an excretory duct with its external orifice in the palpebral conjunctiva. The conjunctival epithelium has fallen off. — 39, A concretion in the excretory duct of an acino-tubular gland close to its external orifice in the palpebral conjunctiva, the epithelium of which has fallen off. This concretion was semi-soft and took up those stains with preference for which mucous substances have a special affinity.

Plate XXI. — 40, Two horizontal sections through the lidmargin. The upper one, from the upper eyelid, goes through the shafts of the eyelashes; the lower one, from the lower eyelid, goes through the bulbs of the eyelashes. Both sections show numerous transverse sections through Meibomian and modified sweat-glands, as light spots. — 41, Vertical (sagittal) section through the margin of the upper eyelid: A, Meibomian gland and its duct; B and E, eyelashes and their sebaceous glands; C, modified sweat-gland; at D, the collecting chamber and excretory duct which does not enter the sebaceous gland of an eyelash, but has a separate orifice at the lidmargin; at F, a part of another modified sweat-gland is seen.

Plate XXII. — 42, Vertical (sagittal) section through the margin of the lower eyelid of a negro. To the left, the conjunctiva, tarsus and a Meibomian gland with its excretory duct below; to the right, the skin of the eyelid; downwards, an eyelash, and just above it a modified sweat-gland with its secretory duct, the external orifice of which lies in the duct of a sebaceous gland; above this the root of an eyelash and the orbicularis muscle. Between the lower end of the Meibomian gland and the sebaceous

gland lies Riolan's muscle. — 43, Horizontal section through the lidmargin at the level of the roots of the eyelashes, showing numerous transverse sections of hair-bulbs and between them modified sweat-glands. Downwards the transverse sections of three Meibomian glands near their lower end. The fibres seen running parallel to the conjunctival surface above the Meibomian glands and those between the modified sweat-glands and the hair-bulbs are the fibres of Riolan's muscle.

Plate XXIII. — 44, 45, Vertical sections, parallel to the surface, through the lid margins of the upper and lower eyelid, showing the modified sweat-gland and (abnormally dilated), between, the roots and shafts of the eyelashes, under a high magnifying power.

Plate XXIV. — 46, Section the same as in Figs. 44 and 45, showing at A, B and C modified sweat-glands under a high power, having an altogether tubular appearance; above them are some acini of a Meibomian gland. — 47, Horizontal section through the lacrymal caruncle of a negro, showing sebaceous glands, the transverse section of a hair (upwards) and an acinous gland at A.

Plate XXV. — 48, Vertical section through a lacrymal caruncle having two acinous glands (A and B). The epithelium has fallen off. — 49, Horizontal section through the lacrymal caruncle. Acinous glands at A.

Plate XXVI. — 50, Similar section to that shown in Fig. 49. — 51, Small body of hyaline cartilage lying in the loose tissue (in one lid only) of the lower eyelid, just below the caruncle. Horizontal section. The conjunctival epithelium has fallen off.

Plate XXVII. — 52, This cartilage under a high magnifying power. — 53, Vertical (sagittal) section through both eyelids passing through the vertical portion of the lacrymal canaliculus of the upper eyelid and its orifice in the lacrymal papilla. The oblique section through the horizontal portion of the canaliculus is seen in the lower eyelid. The canaliculus is filled with desquamated epithelium.

Plate XXVIII. — 54, Horizontal section through the upper eyelid showing the horizontal portion of the lacrymal canaliculus. Below is the lacrymal caruncle. — 55, Section through the axis of the lacrymal papilla and the vertical portion of the lacrymal canaliculus, showing its narrowest part just inside of the lacrymal punctum, from where it widens out gradually to where it bends to form the horizontal portion.

Plate XXIX. — 56, Section like the one in Fig. 55. To the left the horizontal diverticle of the lacrymal canaliculus projects into the tissue of the eyelid (temporally), to the right (nasally) the beginning of the horizontal portion. This section does not pass exactly through the axis of the vertical portion of the canaliculus. — 57, Horizontal section showing a tortuous lacrymal canaliculus.

Plate XXX. — 58, Section through both eyelids and nasal canthus almost parallel to their surface. To the left and downwards, nasal part of the upper, to the right and upwards, nasal part of the lower eyelid; between these the lacrymal caruncle. At the right the horizontal portions of the two canaliculi are seen to join at a sharp angle. — 59, The entrance of the lacrymal canaliculus into the lacrymal sac. The canaliculus lies to the right and is seen to be lined with a thick pavement epithelium; the lacrymal sac to the left is lined with cylindrical epithelium.

Plate XXXI. — 60, Horizontal section through the right lower eyelid (A) and the tissue at the side of the nose. The lacrymal sac at B.

Plate XXXII. — 61, the walls of the lacrymal sac, showing the cylindrical epithelium and lymphatic infiltration, under a high magnifying power. — 62, Acinous glands in the wall of the lacrymal sac at A.

Plate XXXIII. — 63, Similar section to Fig. 62. — 64, Acinous gland of the lacrymal sac. The sac begins to the right downwards; the gland seems to lie some distance from it.

Plate XXXIV. — 65, Another such acinous gland, with an oblique section through its excretory duct. — 66, Several acini of such a gland from the wall of a lacrymal sac, under a high magnifying power.

Plate XXXV. — 67, 68, Glands in the wall of a lacrymal sac which have a more tubular structure.

Plate XXXVI. — 69, Schematic section through both eyelids and eyeball near the nasal canthus. — 70, Schematic section through the middle line of both eyelids and eyeball. — 71, Schematic section through both eyelids and eyeball near the temporal canthus.

Issued July 12, 1900.

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GLANDS APPERTAINING TO HUMAN EYE.

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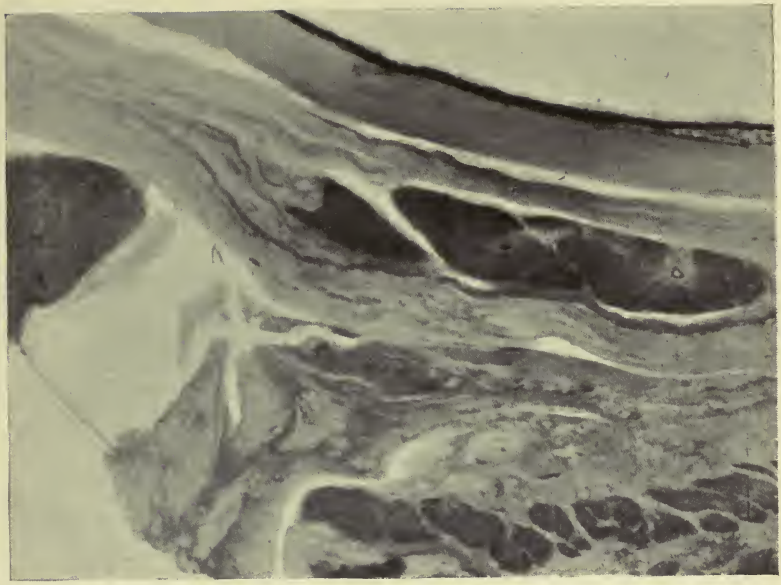

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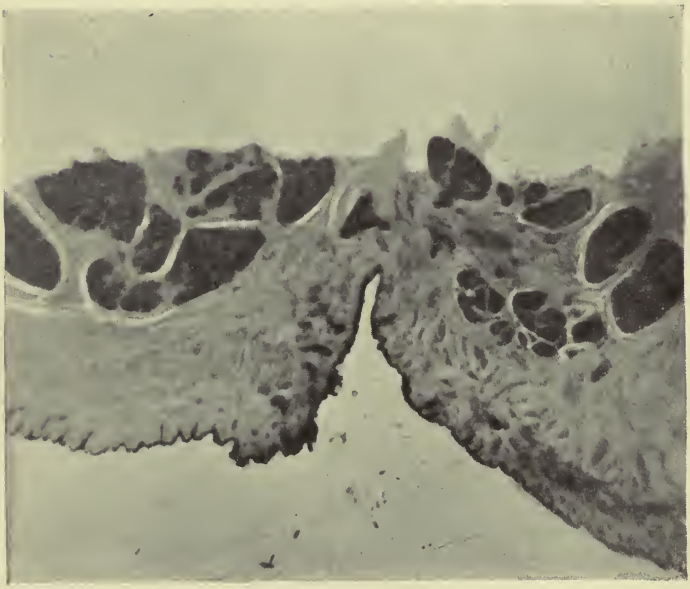

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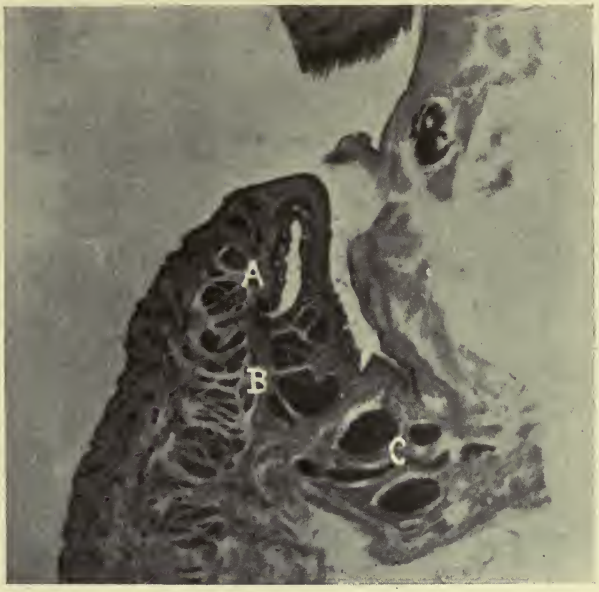

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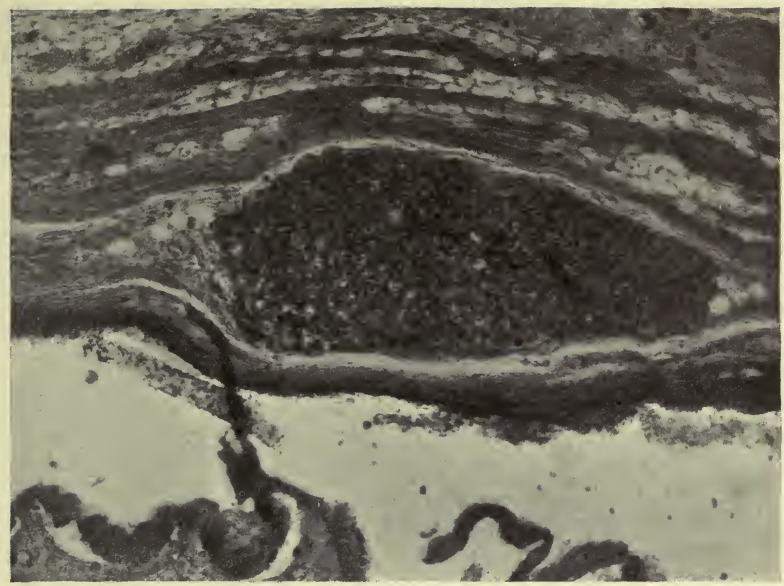

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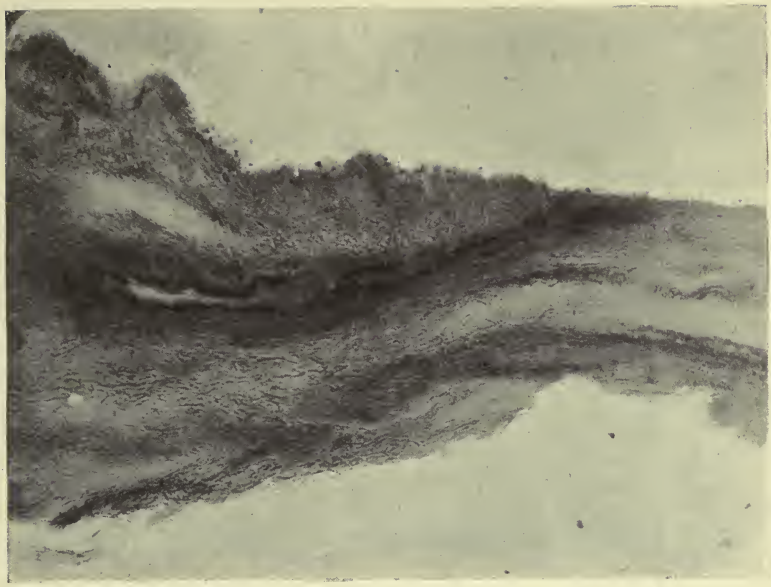

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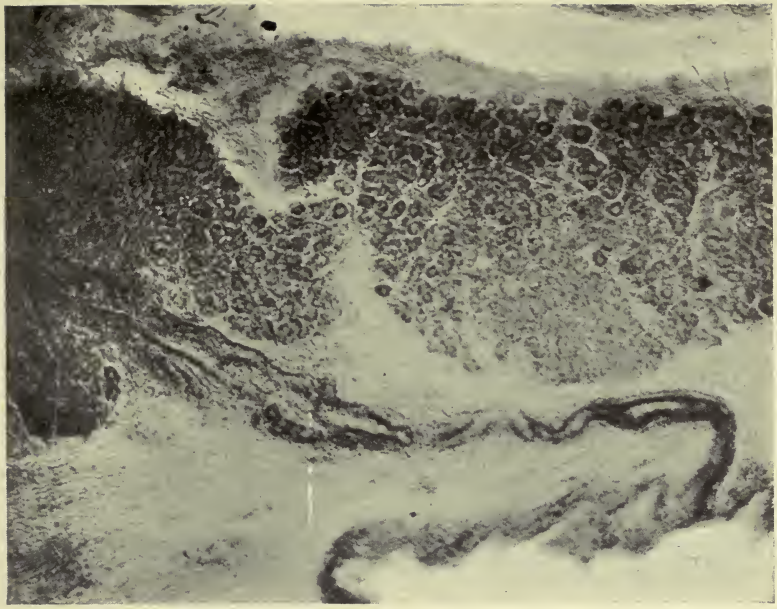

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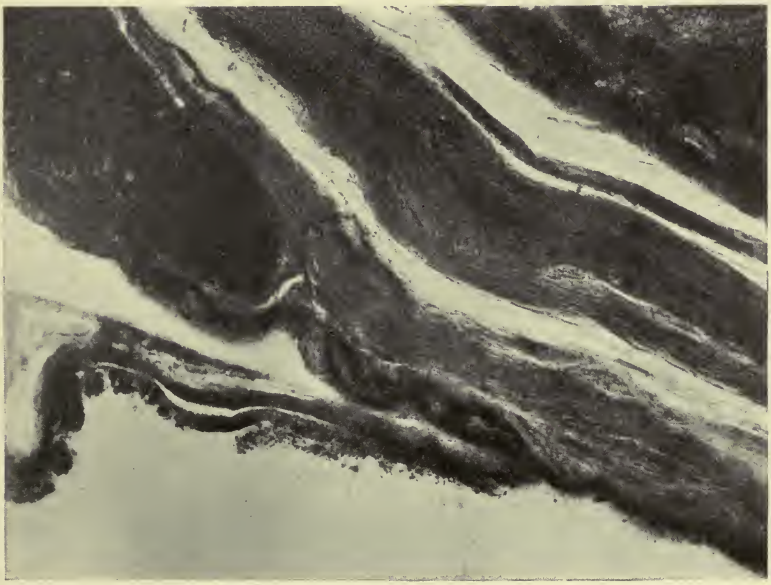

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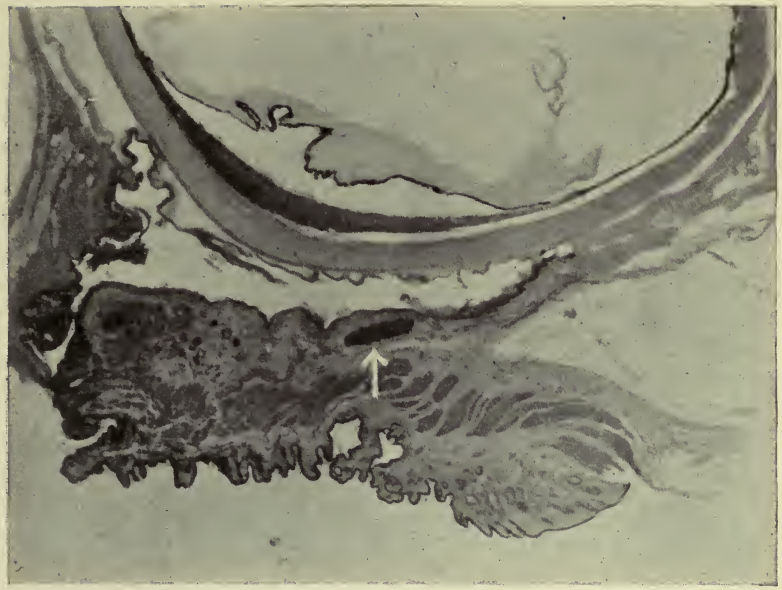

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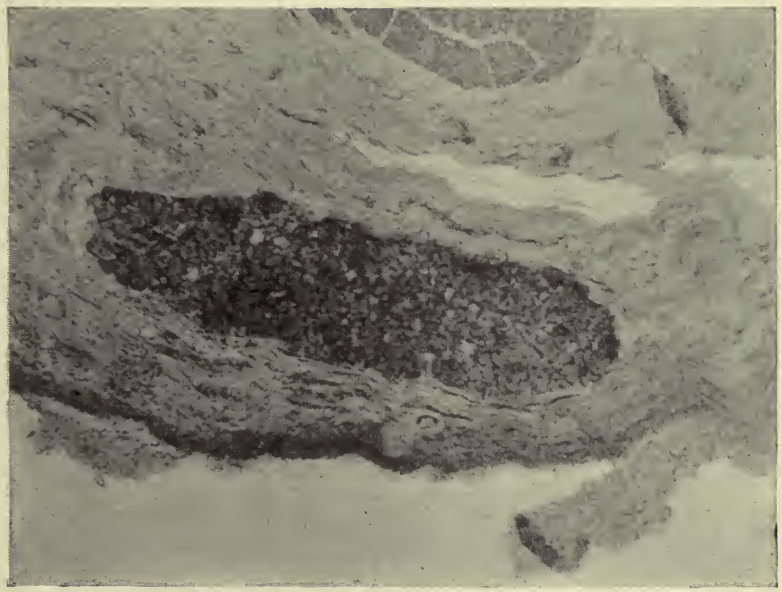

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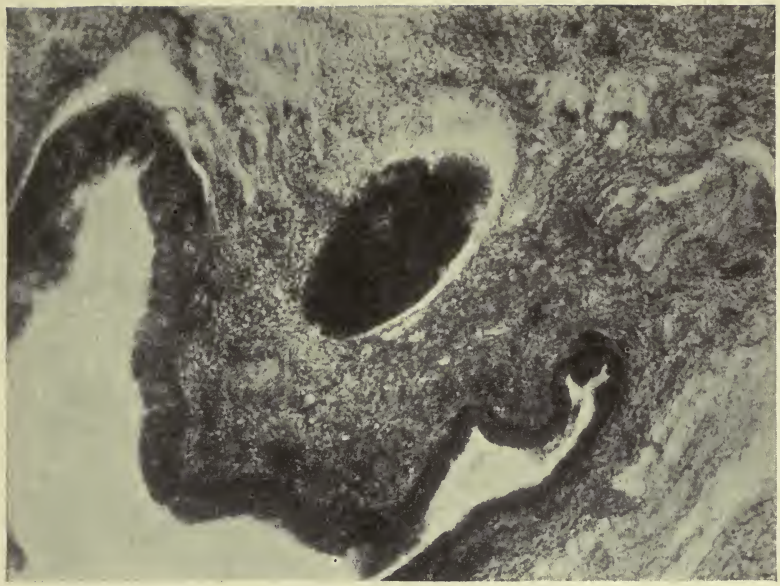

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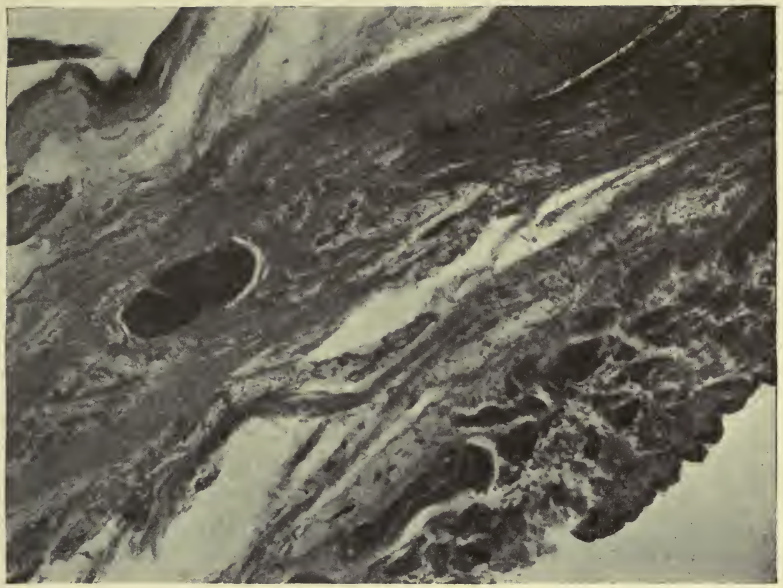

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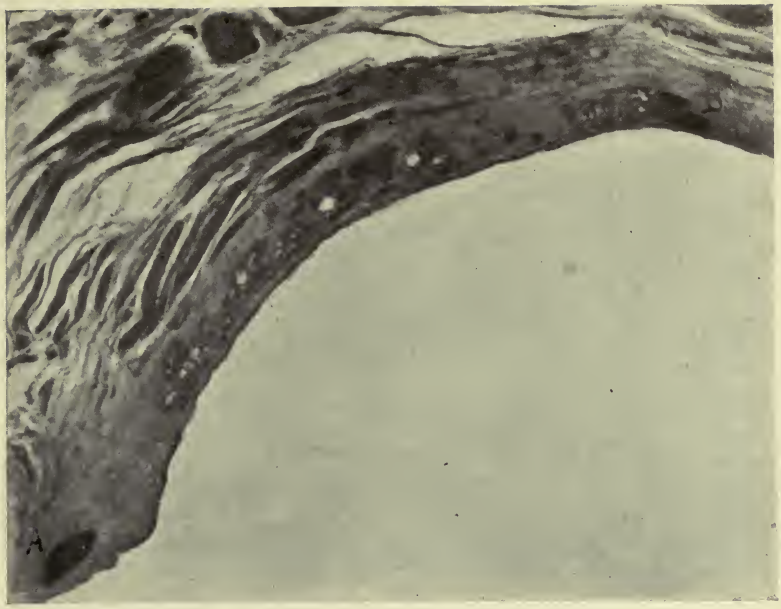

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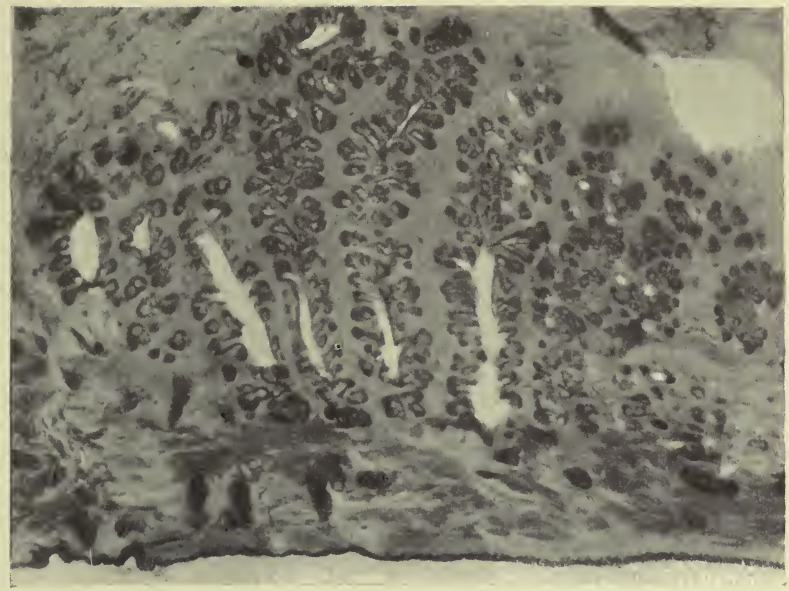

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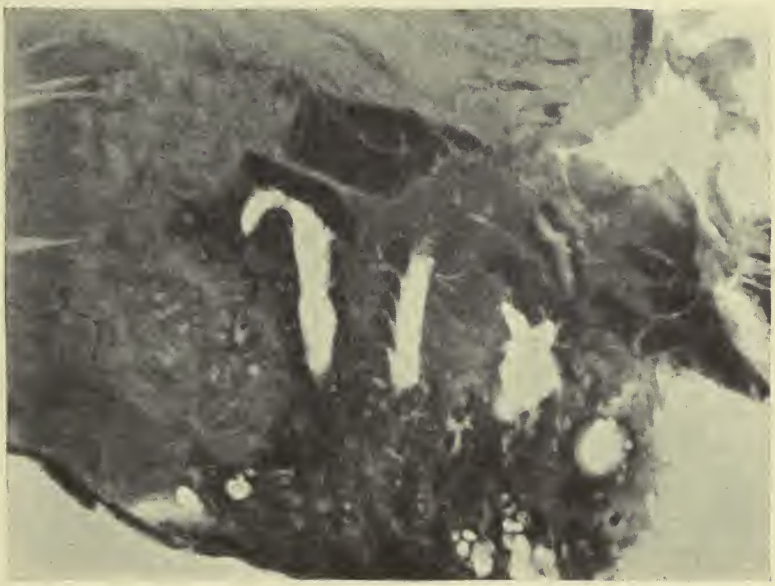

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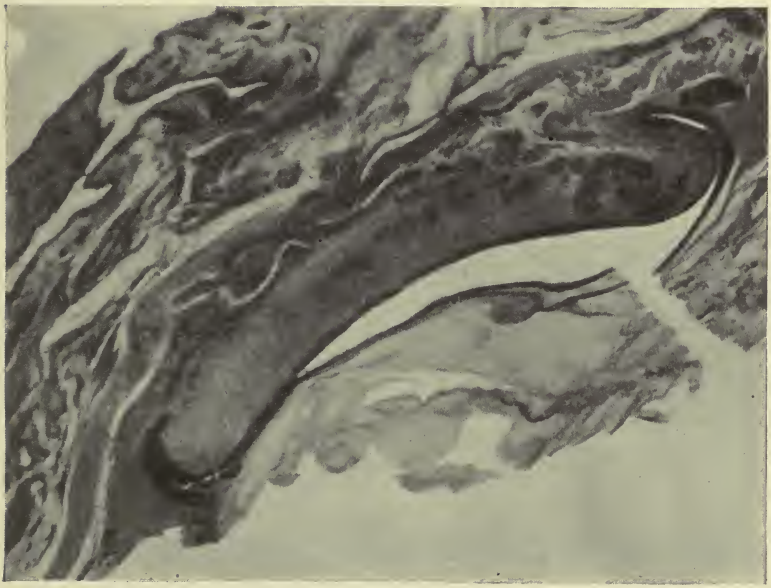

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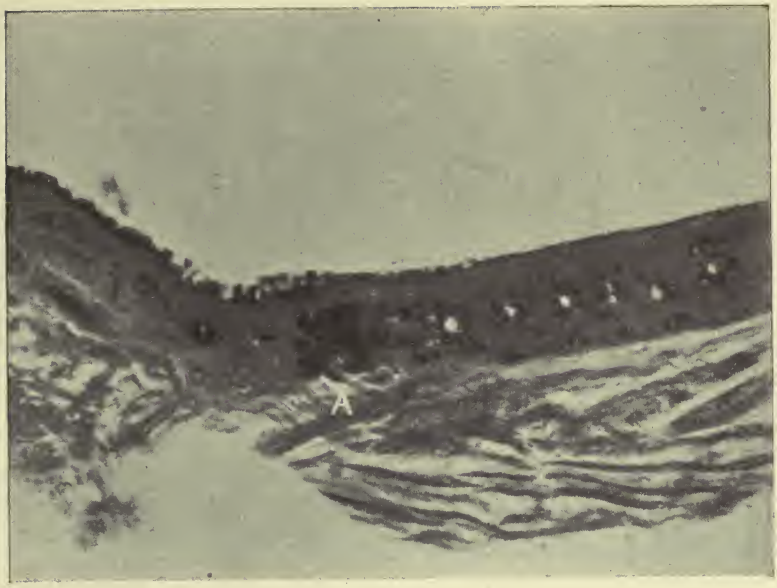

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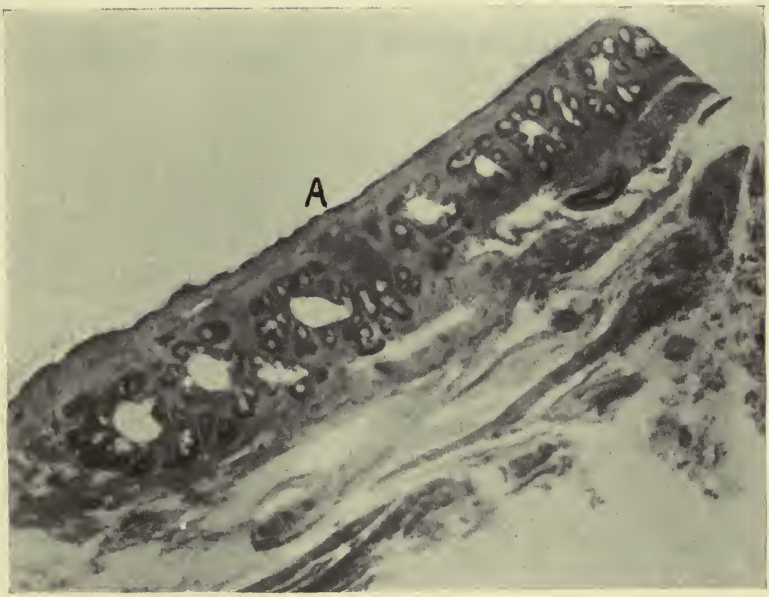

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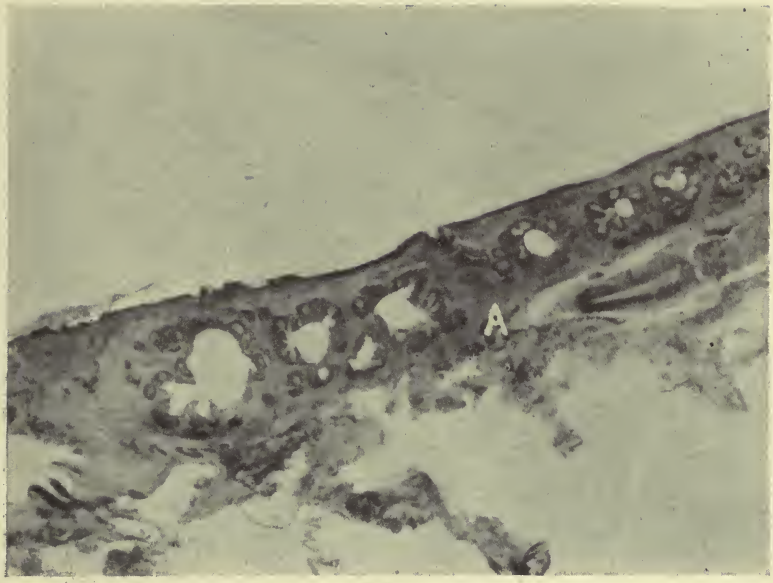

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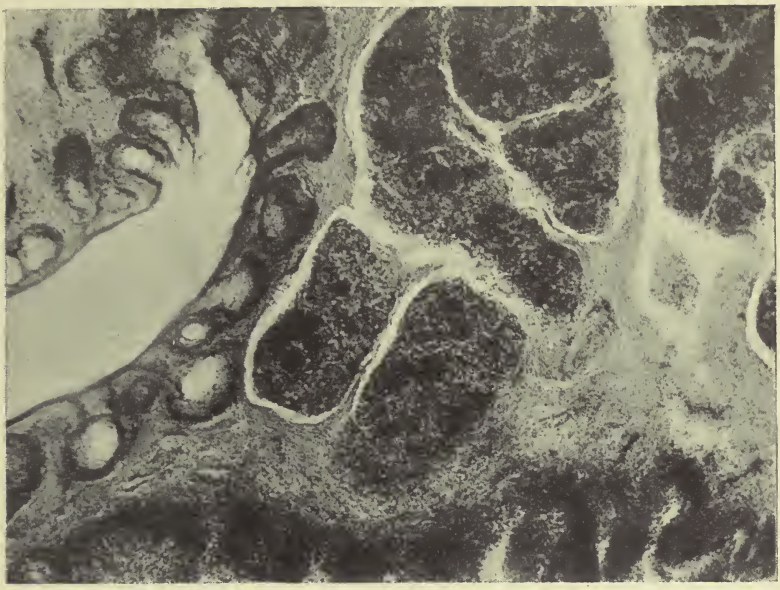

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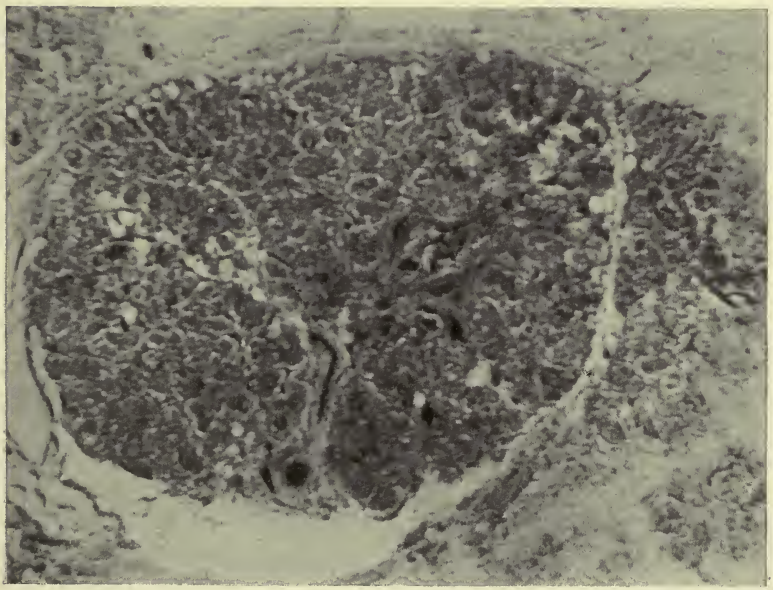

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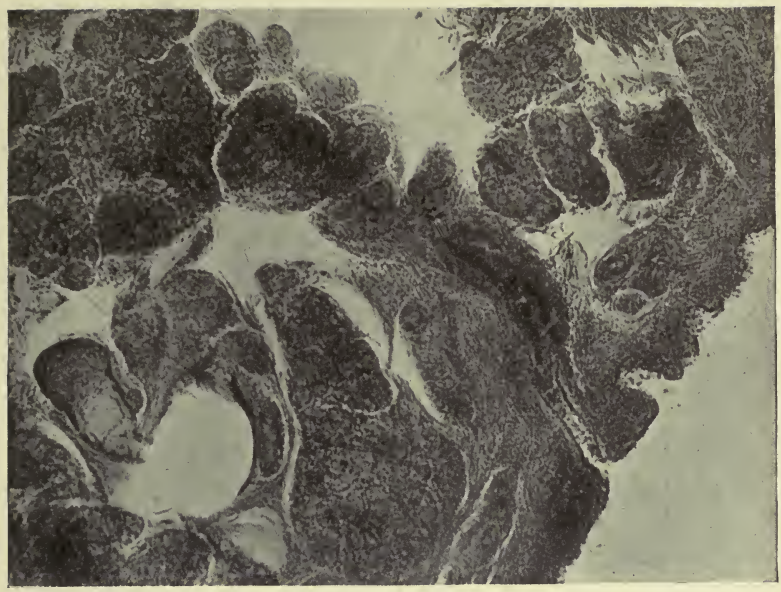

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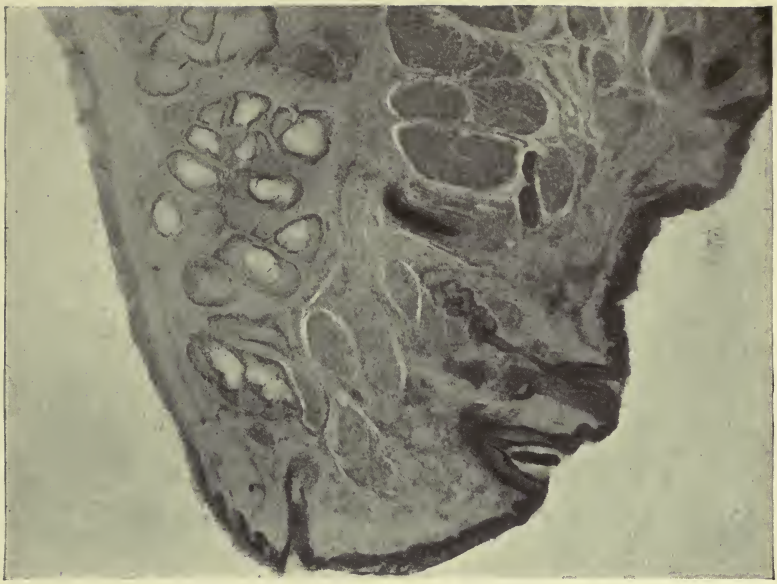
GLANDS APPERTAINING TO HUMAN EYE.



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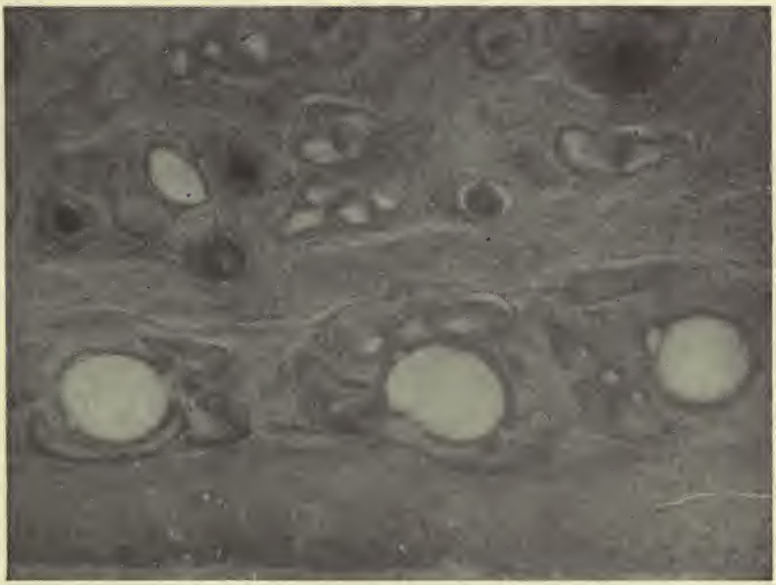

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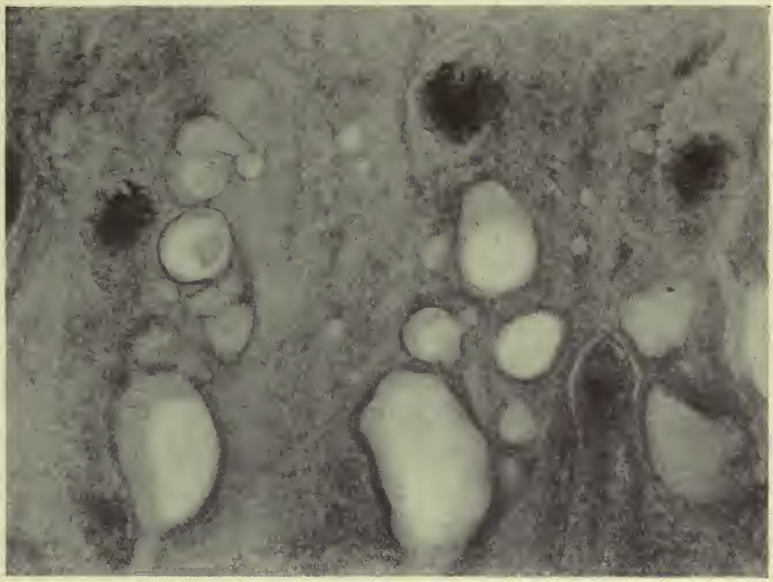
GLANDS APPERTAINING TO HUMAN EYE.



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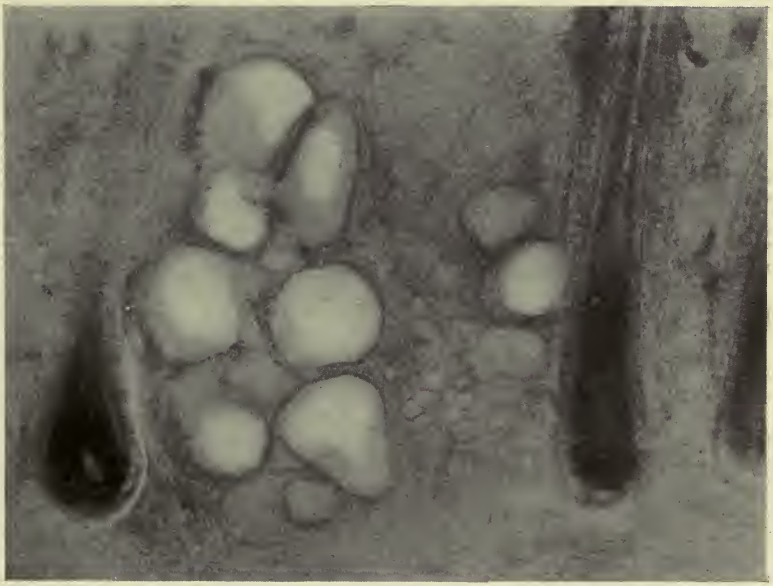

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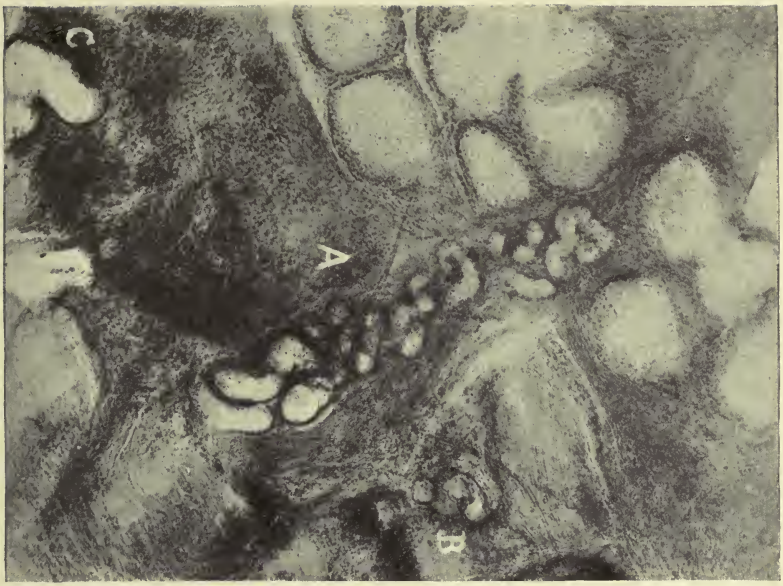

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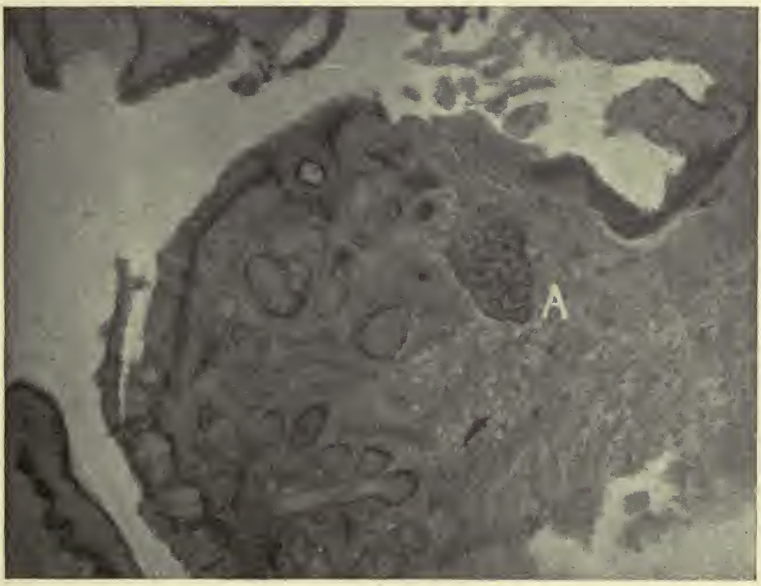

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GLANDS APPERTAINING TO HUMAN EYE.

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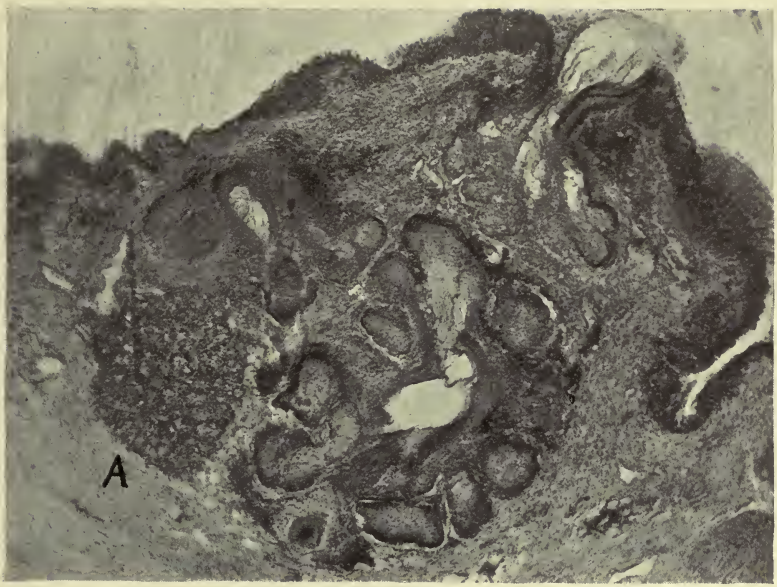

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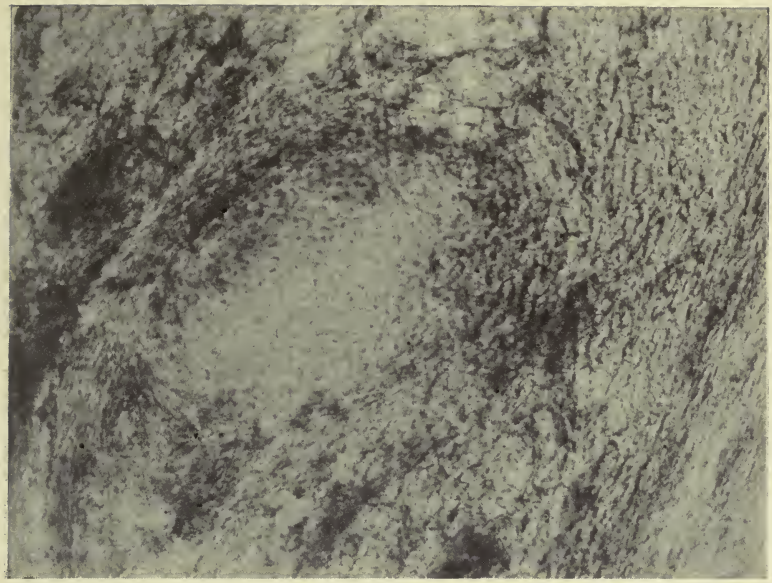

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GLANDS APPERTAINING TO HUMAN EYE.

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GLANDS APPERTAINING TO HUMAN EYE.

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GLANDS APPERTAINING TO HUMAN EYE.

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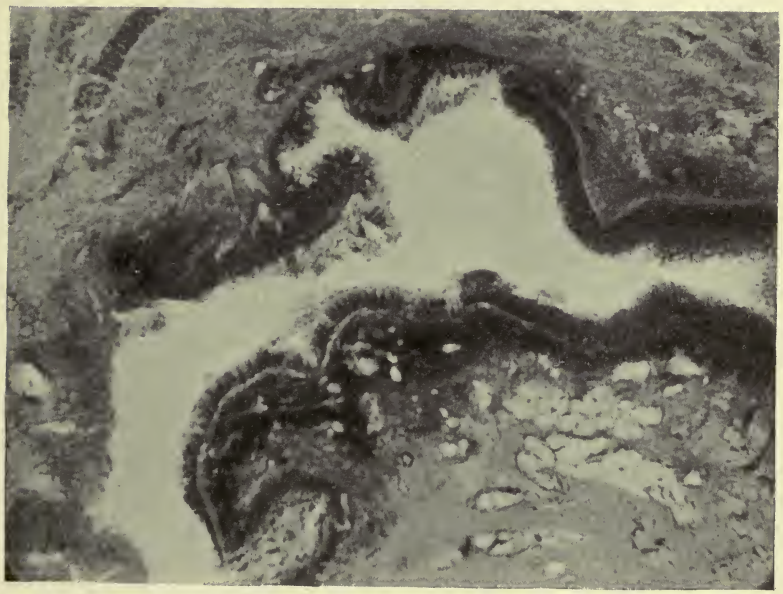

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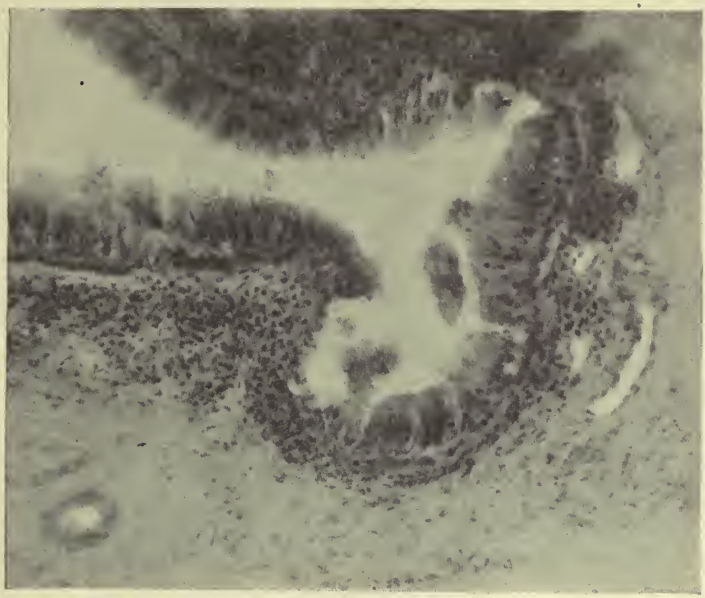

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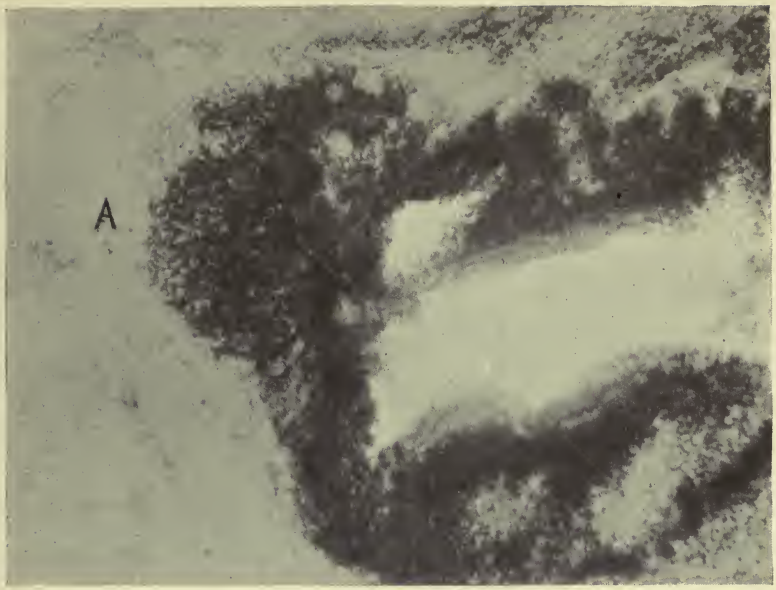

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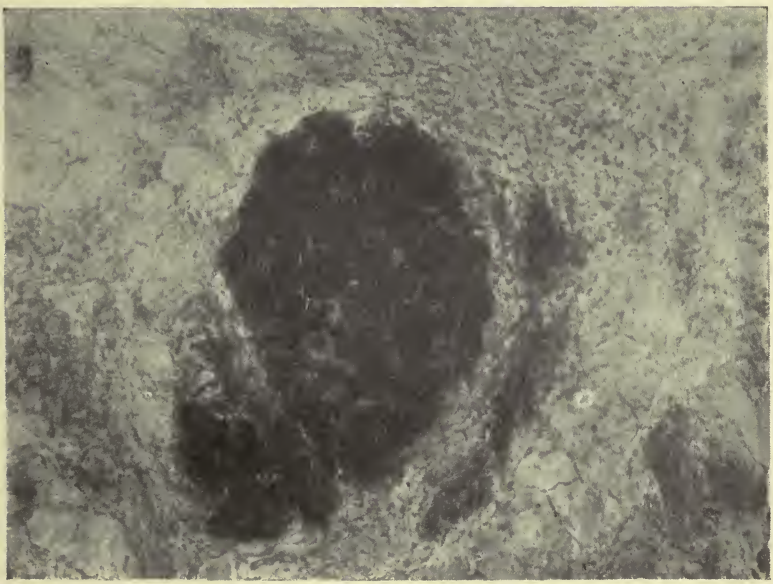

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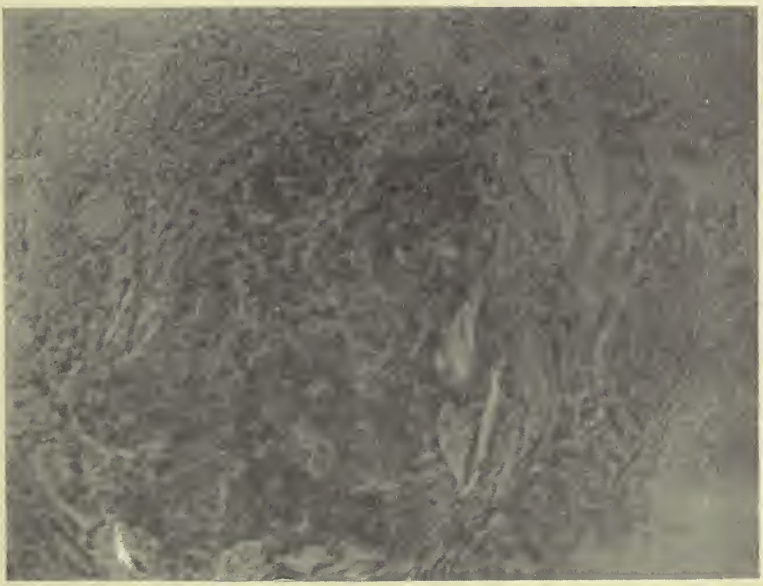

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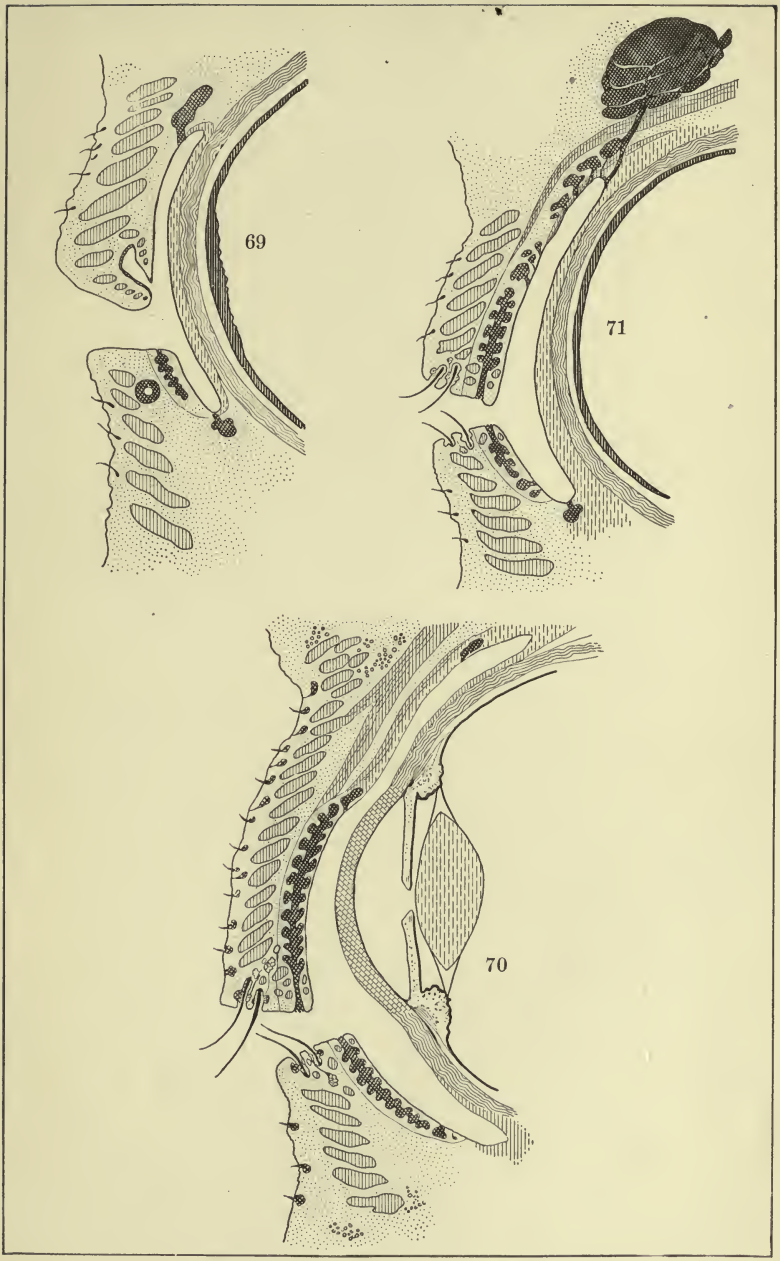

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